

Thermophysical Properties for the Development of Laser-Assisted Surface Modification Processes

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The interaction between a laser beam and the surface of a material, which can be used to modify material properties, introduces heat and mass transfer during the dynamic melting and solidification. The knowledge of the thermophysical properties can be important in order to understand the dominating physical effects and to optimise the laser induced process. We report within this paper on the development of a laser supported process which allows for the fabrication of thermally and electrically conducting lines on ceramic surfaces with a free design (i.e. without using masks) and a good mechanical and thermal coupling to the ceramic substrates.

The laser beam of a high power CO₂-laser is used to heat the surface of the ceramic above his melting point. Metallic particles are introduced into the localised melt pool. After the solidification a metal-ceramic composite has been generated within the laser irradiated trace. In order to generate conducting lines the substrate is moved relative to the laser position with a constant velocity. Different ceramic materials were used in the experiments : Al₂O₃ as a reference material, Cordierite (2MgO.2Al₂O₃.5SiO₂) and the glass ceramics LTCC (Low Temperature Cofired Ceramics). In the present study particles of different powders (W, Cu) were added during the laser induced remelting process.

Different characterisation methods were applied to the ceramic materials before, during and after the laser induced modification process. The thermophysical properties of the ceramic substrates were characterised using standard measurement techniques: The thermal diffusivity were measured by a laser flash method, specific heat by differential scanning calorimetry (DSC) and thermal expansion by a differential push rod dilatometer over a wide temperature range. During the laser process a thermal-imaging system was used to monitor the transient temperature distribution and the heat flow on the ceramic surface. Microstructures of the obtained conducting lines were studied by light and scanning electron microscopy (SEM) and the modified chemical composition were qualitatively analysed by energy dispersive x-rays (EDX). The electrical conductivity was determined by a standard two point measurement technique. The local changes of the thermal conductivity were measured with the photothermal method. With tungsten as an additive material embedded in a Cordierite matrix a specific electrical resistance of the order of $10^{-5} \Omega \text{ m}$ could be obtained. Within these lines an up to 10 times increased thermal conductivity value compared to the pure substrate material Cordierite could be determined with the photothermal method. Using Cu as the additive metal lower values of the electrical resistance and consequently higher local thermal conductivities within the modified region could be obtained.

The measured values of the thermophysical properties has been incorporated into a numerical model which has been used to simulate the laser process.